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Birth Hospital and Racial/Ethnic Differences in Severe Maternal Morbidity in the State of California.

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Abstract

Background: Birth hospital has recently emerged as a potentially key contributor to disparities in severe maternal morbidity, but investigations remain limited.

Objectives: We leveraged state-wide data from California to examine whether birth hospital explained racial/ethnic differences in severe maternal morbidity.

Methods: This cohort study used data on all births ≥20 weeks in California (2007-2012). Severe maternal morbidity during birth hospitalization was measured using the Centers for Disease Control and Prevention index of having at least one of 21 diagnoses and procedures (e.g. eclampsia, blood transfusion, hysterectomy). Mixed effects logistic regression models (i.e. women nested within hospitals) were used to compare racial/ethnic differences in severe maternal morbidity before and after adjustment for maternal sociodemographic and pregnancy-related factors, co-morbidities, and hospital characteristics. We also estimated risk-standardized severe maternal morbidity rates for each hospital (N=245) and the percent reduction in severe maternal morbidity if each group of racially/ethnically minoritized women gave birth at the same distribution of hospitals as non-Hispanic White women.

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Results: Of the 3,020,525 women who gave birth, 39,192 (1.3%) had severe maternal morbidity (2.1% Black; 1.3% US-born Hispanic; 1.3% foreign-born Hispanic; 1.3% Asian/Pacific Islander; 1.1% White; 1.6% American Indian/Alaska Native and Mixed Race referred to as "Other"). Risk-standardized rates of severe maternal morbidity ranged from 0.3 to 4.0 per 100 births across hospitals. After adjusting for covariates, odds of severe maternal morbidity was greater among non-White women compared to Whites in a given hospital (Odds Ratios and 95% Confidence Intervals; Black =1.25 (1.19-1.31), US-born Hispanic=1.25 (1.20-1.29), Foreign-born Hispanic=1.17 (1.11-1.24), Asian/Pacific Islander=1.26 (1.21-1.32), "Other"=1.31 (1.15-1.50). Among the studied hospital factors, only teaching status was associated with severe maternal morbidity in fully adjusted models. Although 33% of White women delivered in hospitals with the highest tertile of severe maternal morbidity rates compared to 53% of Black women, birth hospital only accounted for 7.8% of the differences in severe maternal morbidity comparing Black and White women and accounted for 16.1-24.2% of the differences for all other racial/ethnic groups.

Conclusion: In California, excess odds of severe maternal morbidity among racially/ethnically minoritized women was not fully explained by birth hospital. Structural causes of racial/ethnic disparities in severe maternal morbidity may vary by region, which warrants further examination to inform effective policies.

Keywords

Racial/ethnic disparities; Severe Maternal Morbidity; Hospital-level factors; Health equity

Introduction:

Severe maternal morbidity (SMM) has emerged as a major public health crisis given its potential short and long-term consequences for maternal and infant health.[1,2] In the U.S., the rate of SMM was 144 per 10,000 delivery hospitalizations in 2014, representing a 200% increase from 1993, when the rate was 49.5 per 10,000.[1] Even more alarming are the persistent and pervasive racial/ethnic differences in SMM.[3-5] Black women have a 2-3 fold higher occurrence of SMM compared to White women, and although less pronounced, SMM is also higher in other racially minoritized women compared to White women, including Hispanic/Latino, Asian/Pacific Islander, and Native American women.[6,7]

Factors underlying racial/ethnic disparities in SMM remain poorly understood with most studies documenting that differences persist after adjustment for sociodemographic and clinical characteristics.[4,6-9] Due to a broader recognition of the importance of context (e.g. neighborhoods, hospitals) in shaping racial/ethnic disparities in health more generally, [10-12] hospital quality of care has recently emerged as a potential driver of racial/ethnic disparities in SMM.[13] There is also compelling evidence to support that hospital factors may play a role in influencing SMM risk specifically, as delivery volume and provider practices have been related to maternal and infant outcomes including SMM and maternal mortality.[14-16]

A parallel line of research has shown that comparable to patterns of residential segregation, Black and other racially minoritized women deliver at different hospitals from White women and that these hospitals have a lower quality of care. [14,17-19] Using a Nationwide Inpatient Sample, Howell et al. documented a concentration of Black deliveries with only ¼ of all

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hospitals providing care for ¾ of all Black women in the U.S. Moreover, hospitals with a higher proportion of Black births had higher rates of SMM independent of sociodemographic and clinical factors.[18] Similarly, Creanga et al. found that hospitals serving a higher proportion of racially/ethnically minoritized women performed worse on 12 of 15 quality of care indicators.[19] These studies underscore the critical importance of investigating hospital related factors as contributors to racial/ethnic differences in SMM. However, prior studies have been few and limited to either a small geographic area or the comparison of only one other racial/ethnic group to White women.[14,18,20]

Thus, the overall goal of this study was to determine if hospital factors contribute to racial/ethnic differences in severe maternal morbidity in the state of California. We hypothesized that SMM would vary substantially across hospitals, that hospital-level factors would be associated with SMM, and that adjustment for hospital and hospital characteristics would reduce racial/ethnic differences in SMM.

Materials and Methods:

Study Population and Data Sources

This cohort study used data on all California births (live and stillbirths) delivered at ≥ 20 weeks gestation from 2007-2012 (N=3,117,856). Birth and fetal death certificates were linked to hospital discharge data by the California Office of Statewide Health Planning and Development (OSPHD). We applied the following exclusion criteria: non 1st birth for non-singleton deliveries (to avoid duplicates), invalid hospital identifier, delivery at hospital with less than 100 deliveries per year, and implausible maternal age, leaving a final analytic sample of 3,010,525 infants delivered in 245 hospitals (Supplemental Figure 1). The study protocol was approved by the State of California Committee for the Protection of Human Subjects and the Institutional Review Boards of Stanford University and University of California, Berkeley.

Study Outcome

SMM during the birth hospitalization was assessed using the updated Severe Maternal Morbidity Index, a validated measure developed by the United States Centers for Disease Control and Prevention and its partners for use with administrative and population surveillance data.[1,21] SMM criteria included 21 potentially fatal conditions and life-saving procedures that indicate severe and specific organ-system dysfunction using the diagnosis and procedure codes specified in the International Classification of Disease Clinical Modification 9th Revision (ICD-9-CM). Women with one or more of these conditions were categorized as having SMM (Supplementary Table 1).

Race/Ethnicity

Race and ethnicity data was ascertained from birth certificates (Table 1). Given the large number of Hispanics in the state of California, we split this category into U.S. and foreign-born as a proxy for acculturation. Additionally, due to limited sample size American Indian and Alaska Native categories were combined with Mixed-Race and Other categories, which we refer to as "Other." American Indian and Alaska Native made up 84.8% of this category.

Other Maternal Characteristics

We selected potential confounders, a priori, from an extensive list of sociodemographic and pregnancy-related factors and clinical co-morbidities. Sociodemographic characteristics included maternal age, education, and principal source of payment for delivery, from vital records. Pregnancy-related factors included trimester of prenatal care initiation, plurality (singleton, multiple), obstetric history (combination of parity, previous cesarean birth), pre-pregnancy body mass index category, smoking during pregnancy, and gestational age, from vital records (Table 1). Based on prior studies, a list of 17 clinical comorbidities were also assessed using information from patient discharge records and vital records (see Table 1 for complete list).[8]

Hospital Factors

We considered four hospital characteristics in our analyses: teaching affiliation, level of neonatal care (based on American Academy of Pediatrics quality and standard of care guidelines), delivery volume, and ownership type (Table 1).[14,20]

Statistical Analyses:

All statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC). In descriptive analyses, we used chi-square tests and t-tests to compare the distribution of maternal and hospital factors by SMM and race/ethnicity. To determine whether maternal and hospital factors contribute to racial/ethnic differences in SMM we ran a series of mixed-effects logistic regression models with women nested within hospitals. We report odds ratios given that they are suitable approximations of relative risk, as SMM is a rare outcome and estimates using log-linear models produced identical results.[22] The unadjusted model included only race/ethnicity and additional models sequentially included maternal sociodemographic characteristics (Model 1), pregnancy-related factors (Model 2), clinical comorbidities (Model 3), and hospital-level factors (Model 4).

We calculated risk-standardized SMM rates for each hospital based on a multivariable model that included all covariates except for the hospital-level variables.[23,24] The rates were the ratio of predicted to expected SMM rates, multiplied by the California average SMM rate, consistent with an indirect standardization approach. We calculated the cumulative distributions of births among hospitals ranked from lowest to highest using risk-standardized SMM rates, and a chi-square test was performed to compare the risk-standardized SMM rates across racial/ethnic groups.

We then conducted a potential impact analysis to consider what the probability of SMM overall and by race/ethnicity would be in the hypothetical situation of all women giving birth at the same distribution of hospitals as White women. To do this, we used a substitution estimator to estimate the unobserved counterfactual probability of SMM, if women were to deliver at the same distribution of hospitals as Whites.[25] First, we estimated predicted probabilities of SMM for each mother at each hospital. We did this by using coefficients from our final mixed-effect logistic regression model (Model 4) to estimate the predicted probabilities for each individual at each hospital using a standard formula.[26] The probabilities were then multiplied by hospital weights (the percentage of White mothers who went to each hospital), to get weighted average probabilities of SMM. The sum of the differences between the probability of SMM at the original hospital in which the mother delivered and weighted average probability is the decrease or increase in SMM events if the mother went to the same hospitals as Whites. Second, we estimated the overall predicted probability of SMM among each racial/ethnic group and disparities relative to Whites, as well as the percent change in the predicted probability and disparity, relative to those based on observed values, for each group.

In sensitivity analyses, we excluded women with blood transfusion as their only SMM indicator because it might not truly represent severe cases of SMM (given that information on the volume of the transfusion was not available). [21] We also ran analyses restricting to only singleton births given the etiology of SMM might be different for multiple births.

Results:

Of the 3,010,525 births in California between the years 2007-2012, the mean maternal age was 28.3 (SD=6.3) and the majority of women were Hispanic 51.8% (28.1% foreign-born; 23.7% US born), followed by non-Hispanic White (27.0%), Asian/Pacific Islander (13.1%), Black (5.7%), “Other” (2.2%), Unknown (2.2%). A total of 39,132 (1.3%) of births were SMM births and the prevalence of SMM births was highest in Black/African American women (2.1%) and lowest in White women (1.1%) (Figure 1).

Births occurred at 245 hospitals. The majority (83.9%) occurred at private hospitals and only 11.8% occurred at teaching hospitals (Table 1). Across hospitals the median percentage of births was 27.4% for Non-Hispanic White births, 20.9% for US-born Hispanic births, 23.9% for foreign-born Hispanic births, 2.6% for Black births, and 7% for Asian/Pacific Islander births (data not shown). The median number of births across hospitals was 10,682 (minimum 933, maximum=50,166). Hospital-level unadjusted SMM rates ranged from 0.16% to 5.14%, and risk adjusted SMM rates ranged from 0.33% to 4.03% (Figure 2).

Table 2 shows adjusted risk ratios of SMM by race/ethnicity and hospital characteristics. In unadjusted models, in a given hospital, Black women had doubled risk of SMM compared to Whites (OR=1.99, 95% C.I. 1.92-2.07). US-born Hispanics (OR=1.25, 95% C.I. 1.21-1.29), foreign-born Hispanics (OR=1.24, 95% C.I. 1.21-1.28), Asian/Pacific Islanders (OR=1.24, 95% C.I. 1.20-1.28), and those categorized as “Other” (OR=1.55, 95% C.I. 1.37-1.75) also had a higher risk of SMM compared to White women. Adjustment for sociodemographic factors, pregnancy-related factors, and clinical co-morbidities significantly reduced the excess risk for Black women (OR=1.25, 95% C.I. 1.19-1.31), Foreign-born Hispanic women (OR=1.17, 95% C.I. 1.11-1.24), and “Other” women (OR=1.31, 95% C.I. 1.15-1.50), but not for US-born Hispanic women (OR=1.25, 95% C.I. 1.20-1.29), or Asian/Pacific Islander women (OR=1.26, 95% C.I. 1.21-1.32). Although birth at a teaching hospital was associated with an increased risk of SMM (OR=1.18, 95% C.I. 1.10-1.27), adjustment for hospital factors did not reduce racial/ethnic differences in SMM beyond the sociodemographic and pregnancy-related factors and co-morbidities (Table 2, Model 3). Overall, 6% of the variability in SMM was between hospitals and 94% within hospitals.

Figure 3 shows the crude and risk standardized cumulative distribution of SMM by race/ethnicity and ranked by hospital SMM rates in California. In the unadjusted distribution, 33% of White women gave birth at hospitals in the highest tertile of SMM compared to 52.5% of Black women, 36% of US born Hispanic women, 39.1% of foreign-born Hispanic women, 31.3% of Asian/Pacific Islander women and 40.4% of women categorized as "Other" race/ethnicity. Risk standardized rates that adjust for sociodemographic and clinical characteristics reduced SMM differences between racially/ethnically minoritized groups and White women giving birth in hospitals with the highest tertile of SMM (White=32.9%; Black=38.3%; U.S-born Hispanic=30.7%; foreign-born Hispanic=32%; Asian/Pacific Islander=25.3%; "Other"=39.4%). Finally, results of our simulation model to estimate the number of SMM cases that would have occurred if each racially/ethnically minoritized group gave birth at the same hospitals as White women revealed that there would be 156 fewer SMM cases among Black women had they given birth at the same hospitals as White women which corresponds to a 7.8% reduction in the disparity in SMM between Black and White women (Table 3). The simulation also produced a 12.1% reduction in disparities between the "Other" racial/ethnic group and White women, which would have resulted in 10 fewer SMM cases in this group. Alternatively, there were increases in racial/ethnic disparities for US-born and foreign-born Hispanic women (16.1%, 19.4% respectively) and Asian/Pacific Islander women (24.2%) in the simulation. These increases would have resulted in 272, 412, and 274 additional SMM cases for US born Hispanic, foreign-born Hispanic, and Asian/Pacific Islander women respectively.

Results of our sensitivity analyses revealed that racial/ethnic differences in SMM were comparable for our secondary outcome of non-transfusion SMM and among only singleton births (data not shown).

Comments:

Using data on 3,020,525 births at 245 hospitals in the state of California from 2007-2012, we found that the prevalence of SMM was 1.3% overall and varied considerably by race and ethnicity, with the highest rate of SMM observed in Black women (2.1%) and lowest in White women (1.1%). All racially/ethnically minoritized groups (Black, Hispanic, Asian/PI, and "Other") had significantly higher levels of SMM compared to White women, after adjustment for an extensive set of maternal sociodemographic factors, pregnancyrelated factors, and co-morbidities. Additional adjustment for birth hospital and specific hospital characteristics did not further attenuate racial/ethnic differences in SMM, and only teaching affiliation was associated with SMM. However, in simulation analyses, we found that rates of SMM would be reduced in Black and "Other" women, if they had given birth in the same hospitals as White women.

To our knowledge, this is one of the first studies to examine the contribution of birth hospital to racial/ethnic disparities in SMM in a comprehensive state-wide database of women from diverse racial and ethnic backgrounds. The most comparable studies in this area come from a series of investigations by Howell et al. in New York City (NYC) from 2011-2013.[14,20] They found that racial/ethnic differences in SMM were reduced but remained statistically significant after adjustment for sociodemographic, clinical, and hospital characteristics.

They also found that simulation models designed to predict the rates of SMM for Black women, if they gave birth in similar hospitals as White women, would result in a 47.7% reduction in the disparities in SMM. Simulation models also estimated a 36.5% reduction in Hispanic-White disparities in SMM.[14,20] In our study, we also found that racial and ethnic differences in SMM persisted after adjustment for covariates, and simulation models showed that hospital factors accounted for only 7.8% of the Black-White disparity in SMM. For women in the "Other" racial/ethnic group, which was comprised of mostly Native American women, there was a 13% reduction in disparities based on birth hospital.

There are several potential explanations for why birth hospital was not as strongly predictive of racial/ethnic differences in SMM for the state of California compared to NYC. First, disparities in SMM between Black and White women were less pronounced in California compared to NYC (3 vs. 2 fold higher SMM rates respectively), and Black women also made up a smaller proportion of our study sample (5.7% vs. 21% in NYC) and a smaller proportion of births across hospitals (median percentage of Black deliveries was 2.6% vs. 18.4% in NYC). Alternatively, California has a higher proportion of Hispanic deliveries in compared to NYC (median percentage of Hispanic deliveries of 44.8% vs. 28.7%, respectively) and the Hispanic subgroups vary significantly with California having mostly Mexican women and NYC having more Puerto Rican and Cuban women. Second, there was less variability in SMM rates across hospitals in California compared to NYC with unadjusted SMM rates ranging from 0.16% to 5.15% in CA but 0.6% to 11.5% in NYC. Third, when we investigated whether specific hospital factors were associated with SMM, we found that teaching hospitals had higher SMM rates compared to non-teaching hospitals but no associations with the other hospital factors. The higher risk among teaching hospitals could be due to higher acuity patients and that our risk set for co-morbidities was insufficient given they captured the existence but not severity of co-morbidities. Our null findings for the other hospital factors are supported by mixed findings in the literature. Howell et al. found public hospitals and those with lower nursery level and delivery volume had higher SMM rates compared to private and high nursery level and delivery volume hospitals, respectively.[14,20] Other studies have yielded mixed findings with one assessment in the state of New York in 2013-2014 finding that there were no associations between these factors and SMM, and a national study of hospital-level factors in the U.S. showing that only delivery volume was associated with SMM.[15,27]

Results of our simulation model also provided some counterintuitive findings. We found that for US born/foreign-born Hispanic and Asian/PI women, there was actually an increase in SMM disparities when assigning them to hospitals in which White women gave birth. Our simulation models are based on the assumption that White women give birth at better quality hospitals. This assumption is supported by research documenting that hospitals serving predominately Black and other women from minoritized racial/ethnic groups have worse SMM rates and poorer performance on quality of care metrics.[18,19] However, whether this is true for the state of California remains understudied. Moreover, there is also significant within-hospital variability in SMM outcomes. As an example, Creanga et al. found that even within hospitals that served predominately racially/ethnically minoritized women, Black women received worse quality of care on 11 of 15 metrics.[19] Given substantial research documenting experiences of racial discrimination both within and out of the health care settings and the racial/ethnic differences in outcomes within hospitals,[28,29] future research should examine the factors that may account for both within hospital variation in SMM and racial/ethnic disparities in SMM.

Limitations

This study has several limitations. First, although, we used a validated measure of SMM, there is still a possibility of misclassification due to the under-reporting of the rare SMM conditions in hospital discharge data.[30] There may have also been misclassification due to the inclusion of some women who required a blood transfusion for less severe complications, which we were unable to exclude from our definition of SMM.[21] We did run sensitivity analyses and found that the pattern of racial/ethnic differences were consistent for our secondary outcome of non-transfusion SMM cases, although less pronounced given that this excluded about 50% of our SMM cases. Second, our data end in 2012 since linked birth cohort files were only available through 2012. In California, SMM nearly tripled from 1997-2014,[4] but maternal mortality declined from 2008-2012; we are uncertain of more recent trends, although it is hoped that SMM has not continued to increase, especially in light of quality improvement initiatives implemented by the California Maternal Quality Care Collaborative in more recent years. As such, we are uncertain of the applicability of our results to more recent years but hope to explore this in the future as the linked data become available. Third, the four hospital factors that we included in our analyses were crude proxies for hospital quality and do not reflect disparities in individual level clinical care that impact SMM and have been shown to be vary by race-ethnicity. Moreover, our simulation models were based on the assumption that hospital SMM rates were also a proxy for hospital quality, which may not be the case. Finally, we cannot rule out the potential for residual confounding due to unavailability of data on certain confounders, such as additional measures of SES, which may have resulted in an overestimation of the racial/ethnic disparities in SMM.

Conclusions

This study documented that racial/ethnic differences in SMM are pervasive in California and that birth hospital likely contributes to but does not fully explain these differences, especially for Black women and women categorized as “Other” race/ethnicity. Our work underscores the importance of continued efforts to address disparities in SMM and the need for investigations of the multi-level contributors to these disparities.[31] The potential for regional differences in role of hospital factors in shaping racial/ethnic disparities in SMM also warrants further examination to inform effective policies. Our population-level, hospital-focused approach is important; however, future studies are needed that delve more deeply into the systemic factors (such as racism) that lead to minoritized women giving birth at lower-quality hospitals, and into how this situation may be changed in order to ensure equitable, high-quality maternity care for all.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Condensation:

Using state-wide data from California, this paper investigated if racial/ethnic differences in severe maternal morbidity risk were explained by hospital-level factors.

AJOG at a Glance:

Why was this study conducted?

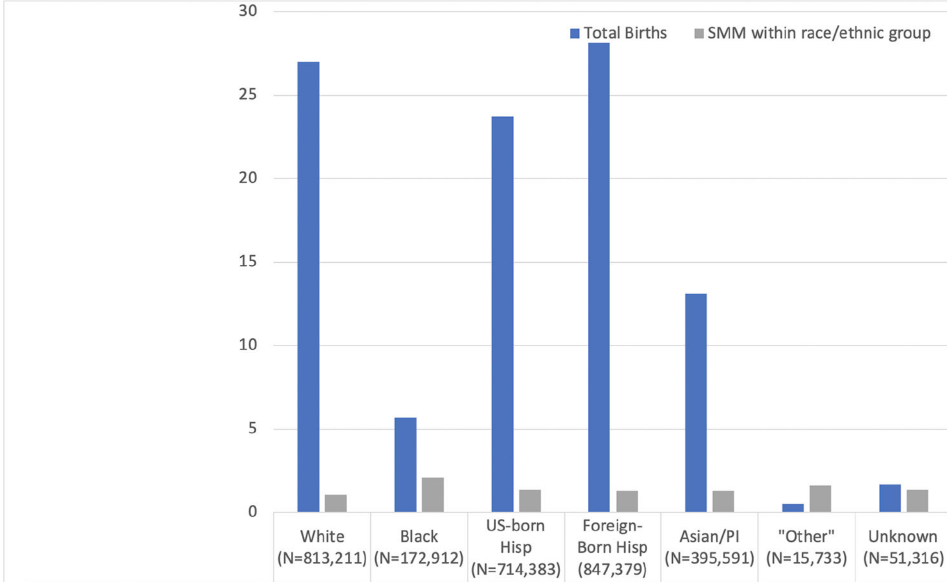
Recent findings in New York City revealed a significant contribution of birth hospital to racial/ethnic differences in severe maternal morbidity (SMM). This study attempted to replicate these findings in the state of California and enhance understanding of regional differences in the role of hospitals in racial/ethnic disparities in SMM.

Key Findings:

We found that, after adjustment, the only hospital characteristic associated with SMM was teaching status; in addition, we found that SMM rates among Black, American Indian/Alaska Native and Mixed-Race women might be modestly reduced, had they given birth in the same hospitals as white women.

What does this study add to what is already known?

This work helps elucidate factors that may contribute to the alarming racial/ethnic disparities in SMM and provides evidence for future investigations of structural factors that may contribute to SMM risk differences across racial/ethnic groups.



	White (N=813,211)	Black (N=172,912)	US-born Hisp (N=714,383)	Foreign-Born Hisp (847,379)	Asian/PI (N=395,591)	"Other" (N=15,733)	Unknown (N=51,316)
Total Births	27	5.7	23.7	28.1	13.1	0.5	1.7
SMM within race/ethnic group	1.06	2.1	1.33	1.32	1.32	1.64	1.36

Figure 1. Proportion of Total and SMM Births by Race/Ethnicity in California (2007-2012); N= 3,010,525

Summary of the distribution of total births and births with severe maternal morbidity (SMM) in the state of California between the years 2007-2012. Black women had the highest proportion of births with SMM while White women had the lowest prevalence of SMM births. All other racial groups also had a higher number of SMM births compared to White women.

“Other” refers to American Indian/Alaska Native and Mixed-Race, and Other women.

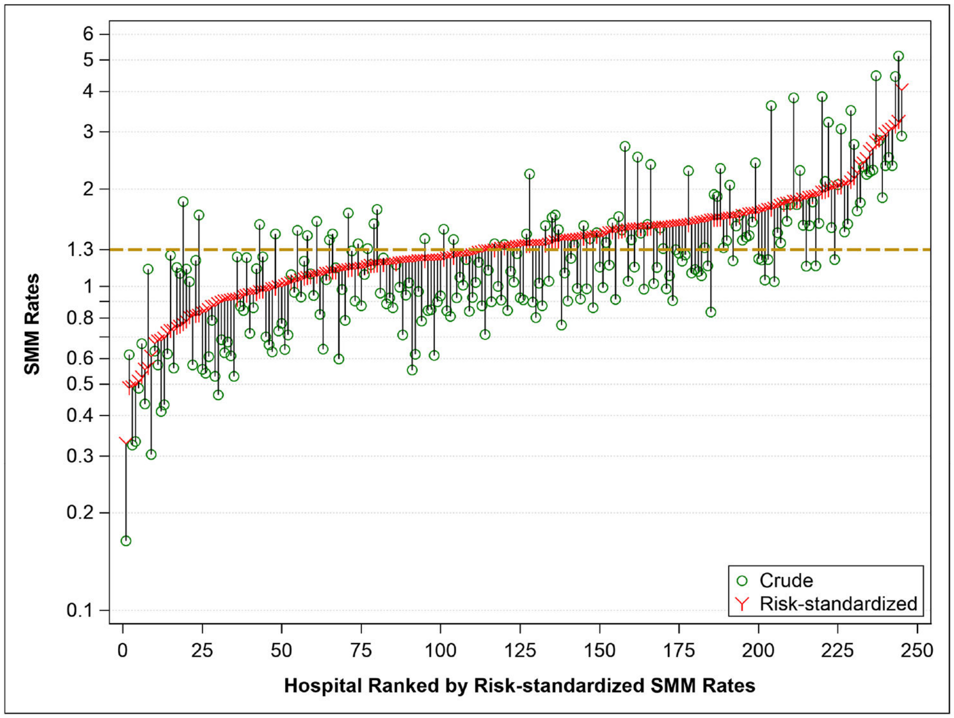


Figure 2: Crude and Risk-Standardized SMM Rates Ranked by Hospital SMM Rate in California (2007-2012); N= 245.

The distribution of risk-standardized severe maternal morbidity (SMM) rates across ranked hospital-level unadjusted SMM rates in the state of California between the years 2007-2012. The range of unadjusted hospital-level SMM rates was between 0.16% to 5.15%, while the range of risk adjusted SMM rates was between 0.19% to 4.18%.

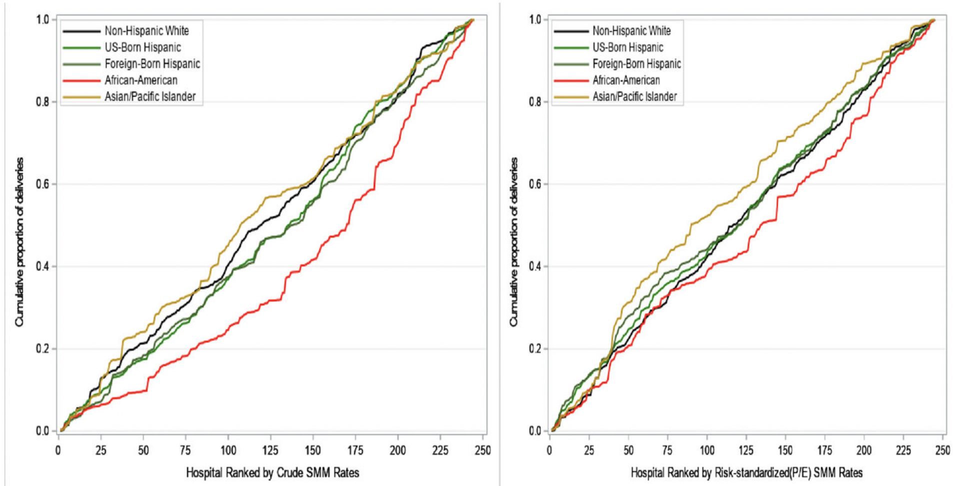


Figure 3. Crude and Risk Standardized Cumulative Distribution of Deliveries by Race/Ethnicity and Ranked by Hospital SMM Rates in California (2007-2012); N=245.

Distribution of crude and risk standardized cumulative rate of severe maternal morbidity (SMM) overall and within racial/ethnic groups, ranked by hospital SMM rates in the state of California between the years 2007-2012. Adjusting for sociodemographic and clinical characteristics (risk standardized rates) decreased the difference in SMM differences between racial groups delivering in hospitals with the highest tertile of SMM.

Crude Cumulative Distribution (Left Panel)

Risk Standardized Cumulative Distribution (Right Panel)

Table 1.

Patient Characteristics Overall and by Severe Maternal Morbidity in California (2007-2012); N= 3,010,525.

	Overall		Severe Maternal Morbidity	
	3010525 (100%)		Yes 39132 (1.30%)	No 2971393 (98.70%)
	N	%	%	%
Maternal characteristics				
Sociodemographic factors				
Maternal Age (Mean=28.3, SD=6.3)				
<20	264910	8.8	10.2	8.8
20-29	1446009	48	42.7	48.1
30-34	756848	25.1	23.8	25.2
35-39	428706	14.2	17	14.2
40-44	105910	3.5	5.7	3.5
45+	8142	0.3	0.7	0.3
Maternal Race/Ethnicity				
White	813211	27	22.1	27.1
US-Born Hispanic	714383	23.7	24.3	23.7
Foreign-Born Hispanic	847379	28.1	28.6	28.1
Black	172912	5.7	9.3	5.7
Non-Hispanic Asian/Pacific Islander	395591	13.1	13.3	13.1
“Other”	15733	0.5	0.7	0.5
Unknown	51316	1.7	1.8	1.7
Maternal Education				
Less than HS	727152	24.2	27.7	24.1
HS	767400	25.5	25.5	25.5
Greater than HS	1409360	46.8	42.9	46.9
Unknown/Missing	106613	3.5	3.9	3.5
Principal Source of Payment for Delivery				
Medi-Cal	1452579	48.3	52.3	48.2
Private	1403031	46.6	42.3	46.7
Uninsured	64193	2.1	2.2	2.1
Other	84955	2.8	2.8	2.8
Unknown/Missing	5767	0.2	0.5	0.2
Pregnancy-related factors				
Trimester prenatal care begun				
No prenatal care	14466	0.5	1.4	0.5
1st trimester	2444875	81.2	76.4	81.3
2nd trimester	399280	13.3	14.1	13.3
3rd trimester	79355	2.6	3.2	2.6
Unknown/Missing	72549	2.4	4.9	2.4

	Overall		Severe Maternal Morbidity	
Type of pregnancy				
Singleton	2960881	98.4	93.4	98.4
Multiple	49644	1.6	6.6	1.6
Parity and previous cesarean				
Nulliparous	1192491	39.6	43.2	39.6
Multiparous, no prior cesarean	441706	14.7	22.1	14.6
Multiparous, prior cesarean	1369664	45.5	34	45.6
Unknown/Missing	6664	0.2	0.7	0.2
Pre-pregnancy BMI				
Underweight	112612	3.7	4	3.7
Normal Weight	1370050	45.5	43.4	45.5
Overweight	714073	23.7	23.4	23.7
Obesity class I	489604	16.3	16.4	16.3
Obesity class II/III	82920	2.8	3.3	2.7
Missing BMI	241266	8	9.6	8
Cigarette Smoking during Pregnancy				
No	2896484	96.2	94.9	96.2
Yes	68653	2.3	2.8	2.3
Unknown/Missing	45388	1.5	2.3	1.5
Gestational age				
<32 wks	41149	1.4	7.5	1.3
32-36 wks	206991	6.9	17.8	6.7
37-42 wks	2753445	91.5	74.3	91.7
Unknown/Missing	8940	0.3	0.4	0.3
Clinical Co-morbidities				
Asthma/chronic pulmonary				
No	2931984	97.4	95.6	97.4
Yes	78541	2.6	4.4	2.6
Blood disorder				
No	2793856	92.8	55.5	93.3
Yes	216669	7.2	44.5	6.7
Cardiac				
No	3003223	99.8	98.2	99.8
Yes	7302	0.2	1.8	0.2
Central nervous system				
No	2987567	99.2	98.1	99.3
Yes	22958	0.8	1.9	0.7
Collagen/vascular				
No	3009808	100.0	99.9	99.98
Yes	717	0.0	0.1	0.02
Digestive				
No	3009584	100.0	99.9	100.0

	Overall		Severe Maternal Morbidity	
Yes	941	0.0	0.1	0.0
Pregnancy diabetes				
No	2983980	99.1	97.8	99.1
Yes	26545	0.9	2.2	0.9
Pregnancy hypertension				
No	2907873	96.6	84.8	96.7
Yes	102652	3.4	15.2	3.3
Lupus				
No	3007518	99.9	99.5	99.9
Yes	3007	0.1	0.5	0.1
Mental disorder				
No	2918815	97	93.1	97
Yes	91710	3	6.9	3
Musculoskeletal				
No	3004642	99.8	99.3	99.8
Yes	5883	0.2	0.7	0.2
Disorder of placentation				
No	2962849	98.4	88.5	98.5
Yes	47676	1.6	11.5	1.5
Pre-Pregnancy Diabetes				
No	2985840	99.2	98	99.2
Yes	24685	0.8	2	0.8
Chronic hypertension				
No	2978884	98.9	97.6	99
Yes	31641	1.1	2.4	1
Renal				
No	3008913	99.9	99.2	99.96
Yes	1612	0.1	0.8	0.04
Rheumatic heart				
No	3009915	100.0	99.7	100.0
Yes	610	0.0	0.3	0.0
Rheumatoid arthritis				
No	3008249	99.9	99.9	99.9
Yes	2276	0.1	0.1	0.1
Hospital Characteristics				
Teaching hospital				
No	2653883	88.2	82.4	88.2
Yes	356642	11.8	17.6	11.8
AAP Level				
Level I	401999	13.4	11.7	13.4
Level II	616829	20.5	18.6	20.5
Level III	1600604	53.2	52.6	53.2

	Overall		Severe Maternal Morbidity	
Level IV	361725	12	16.4	12
Unknown/Missing	29368	1	0.6	1
Nursery level				
CAH	16944	0.6	0.6	0.6
Level I & not CAH	389375	12.9	11.1	13
Level II	574332	19.1	17	19.1
Level III & IV	1855230	61.6	65.2	61.6
Unknown/Missing	174644	5.8	6.1	5.8
Delivery volume				
Low	187315	6.2	5.8	6.2
Medium	484136	16.1	15.2	16.1
High	829508	27.6	31.2	27.5
Very high	1509566	50.1	47.7	50.2
Hospital Ownership				
Public	478456	15.9	21.7	15.8
Private	2524570	83.9	78	83.9
Unknown/Missing	7499	0.2	0.3	0.2

“Other”= American Indian/Alaska Native and Mixed-Race, and Other women

Table 2.

Adjusted Risk Ratios of Severe Maternal Morbidity by Race/Ethnicity and Hospital Characteristics, California 2007-2012; N= 3,010,525.

	Unadjusted OR	Model 1	Model 2	Model 3	Model 4
	OR (95% C.I.)	OR (95% C.I.)	OR (95% C.I.)	OR (95% C.I.)	OR (95% C.I.)
Race/ethnicity					
White	Ref	Ref	Ref	Ref	Ref
Black	1.99 (1.92-2.07)	1.76 (1.69-1.84)	1.68 (1.61-1.75)	1.25 (1.19-1.31)	1.25 (1.19-1.31)
US-born Hispanic	1.25 (1.21-1.29)	1.29 (1.24-1.33)	1.32 (1.28-1.37)	1.25 (1.20-1.29)	1.25 (1.20-1.29)
Foreign-born Hispanic	1.24 (1.21-1.28)	1.12 (1.07-1.18)	1.18 (1.12-1.24)	1.17 (1.11-1.24)	1.17 (1.11-1.24)
Asian/PI	1.24 (1.20-1.28)	1.27 (1.21-1.32)	1.29 (1.23-1.34)	1.26 (1.21-1.32)	1.26 (1.21-1.32)
"Other"	1.55 (1.37-1.75)	1.45 (1.28-1.65)	1.44 (1.27-1.63)	1.31 (1.15-1.49)	1.31 (1.15-1.50)
Unknown	1.28 (1.19-1.39)	1.08 (0.97-1.19)	1.03 (0.93-1.13)	1.00 (0.90-1.10)	0.99 (0.89-1.10)
Hospital Characteristics					
Teaching Hospital					
Yes vs No					1.18 (1.10-1.27)
AAP Nursery Level					
I					0.91 (0.71-1.18)
II					0.87 (0.69-1.09)
III					0.92 (0.74-1.13)
IV					Ref
Delivery Volume					
Low					1.20 (0.97-1.48)
Medium					1.10 (0.93-1.30)
High					1.15 (0.99-1.32)
Very High					
Ownership					
Public vs. Private					1.05 (0.94-1.17)

Model 1: adjusts for sociodemographic factors

Model 2: + pregnancy related behaviors

Model 3: + clinical factors

Model 4: + hospital factors

"Other"= American Indian/Alaska Native and Mixed-Race, and Other women

Table 3:

Reduction in Severe Maternal Morbidity by Race/Ethnicity and Birth Hospital

	# Deliveries	Observed SMM Rate		Simulation			
		SMM (%)	Disparity (%) (A)	SMM (%)	Disparity (%) (B)	% reduction in disparity (C)	# SMM Events avoided (D)
White	813,211	1.06	--	--	--	--	--
Black	172,912	2.10	1.03	2.01	0.95	7.8	156
US-born Hispanic	714,383	1.33	0.26	1.37	0.31	16.1^{+}	272^{+}
Foreign-born Hispanic	847,379	1.32	0.25	1.37	0.31	19.4^{+}	412^{+}
Asian/PI	395,591	1.32	0.25	1.39	0.33	24.2^{+}	274^{+}
"Other"	15,733	1.64	0.58	1.57	0.51	12.1	10

SMM=Severe Maternal Morbidity

"Other"= American Indian/Alaska Native and Mixed-Race, and Other women

Column (A): Disparity=Difference in Observed SMM % between each racial/ethnic group and White women

Column (B):Disparity-Difference in Simulation SMM % between each racial/ethnic group and White women

Column (C): Percent reduction= ((Column A-Column B)/Column A)*100)

$^{+}$indicates an increase instead of a reduction in disparity and # of SMM events

Simulation

Column (D): Details on calculation provided in Supplemental Table 2